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(54) **DIVERSITY TRANSCEIVER FOR A WIRELESS LOCAL AREA NETWORK**

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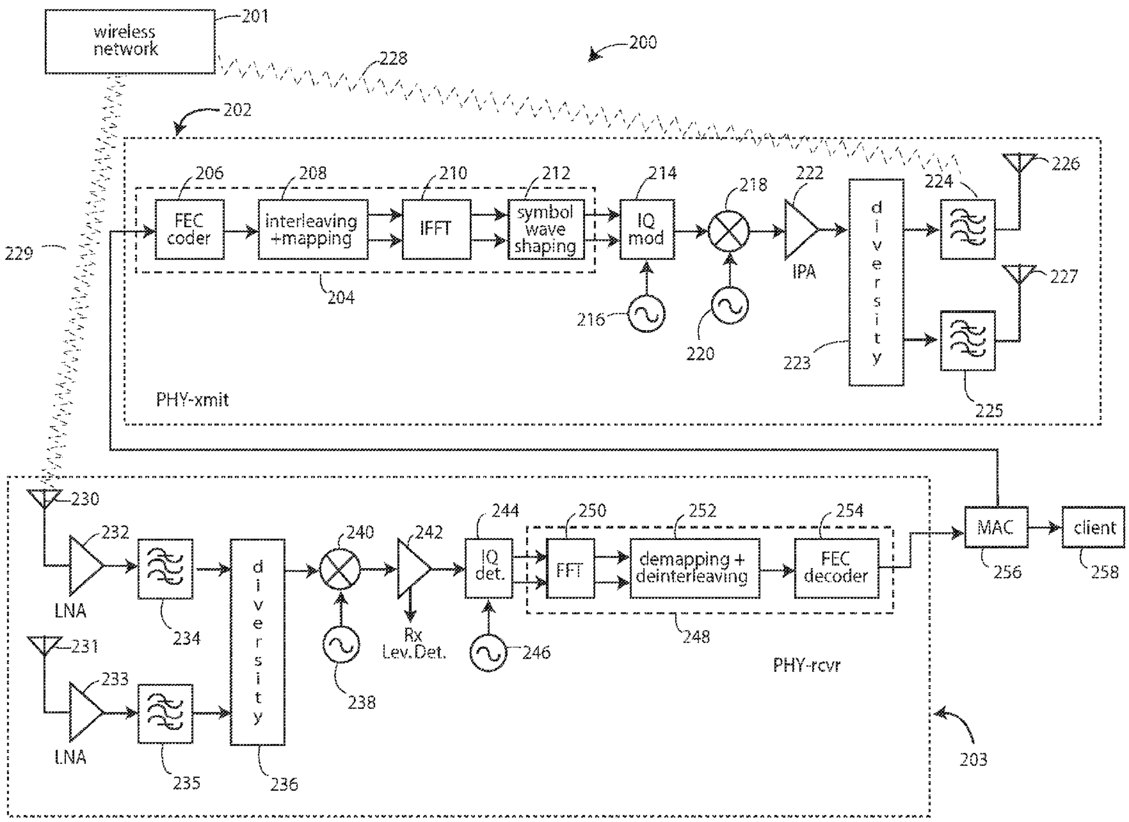
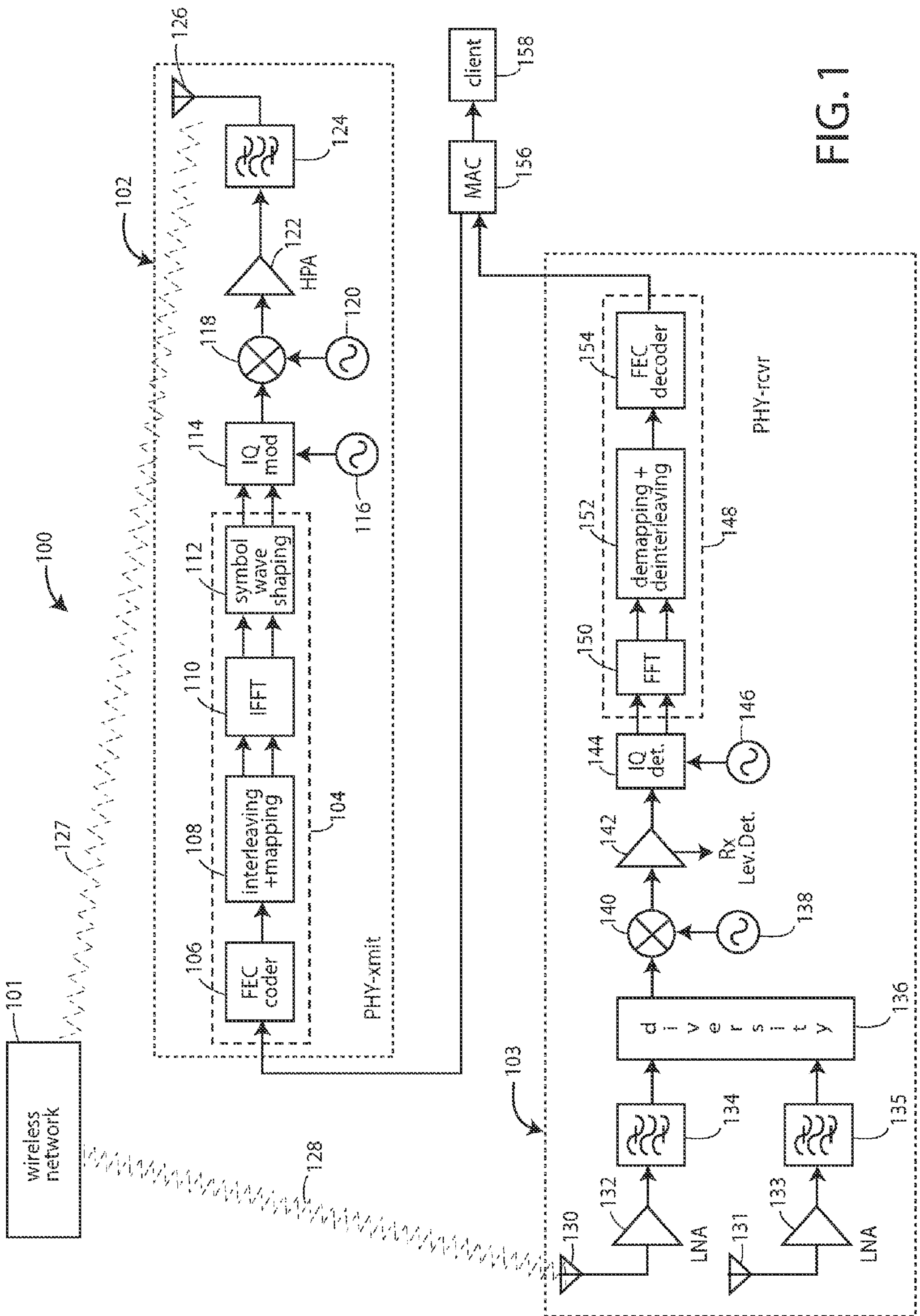
(57) **ABSTRACT**

A wireless local area network system comprises a 5.0+ GHz radio transceiver with two receiving antennas and one transmitting antenna. A transmitter power amplifier output is connected to the transmitting antenna through a 6-8 pole filter to control spurious signal output. Each receiving antenna is fitted with its own low-noise amplifier followed by a simple bandpass filter. Each bandpass filter feeds a diversity switch with a single output to a single receiver. The radio system constitutes a physical-layer (PHY) part of a wireless local-area network.

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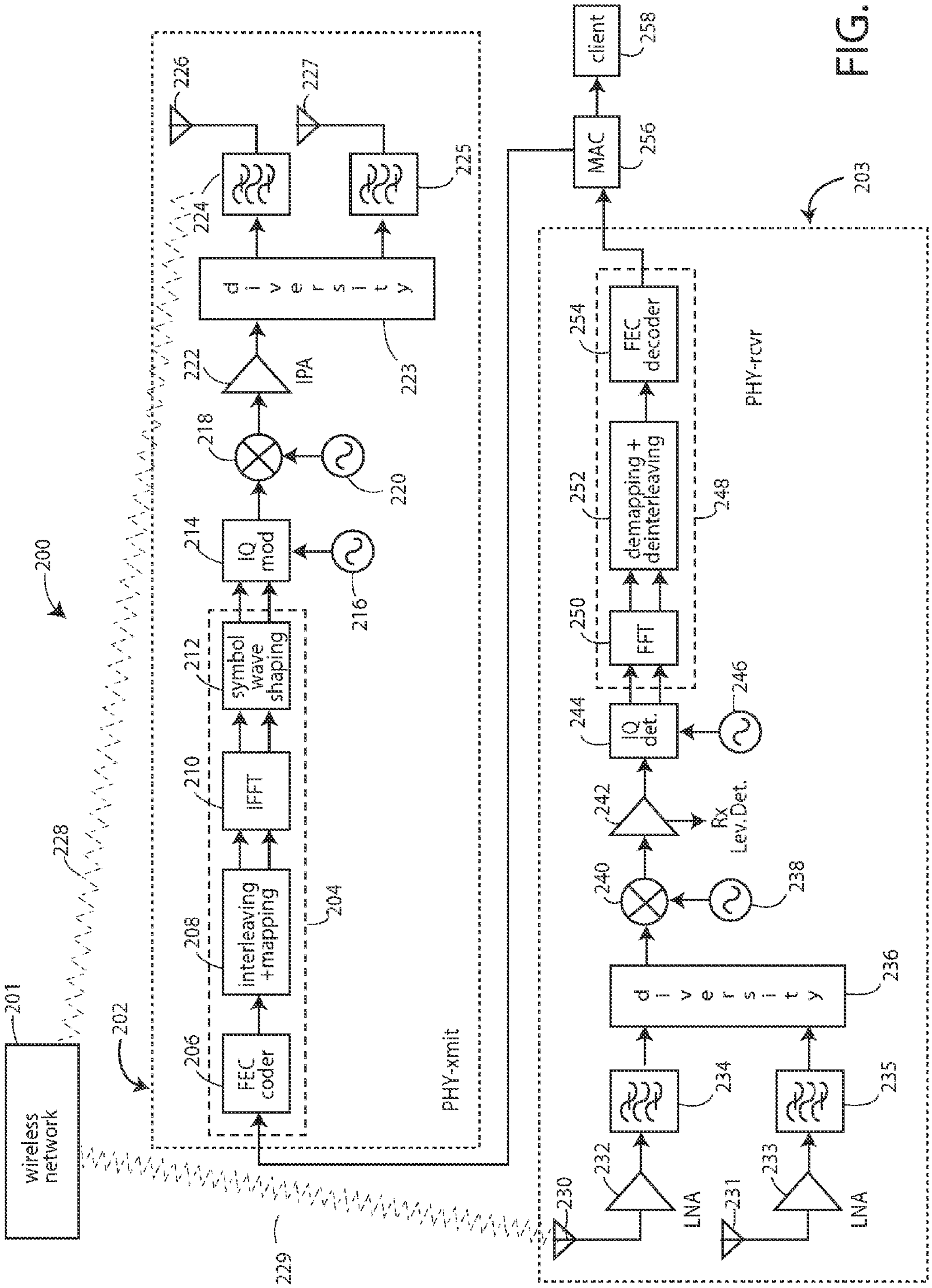
client

FIG. 1



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demapping + deinterleaving
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client

FIG. 2

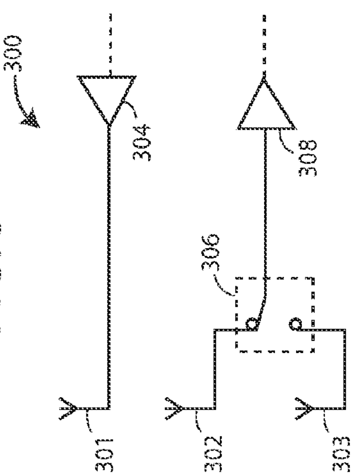

FIG. 3

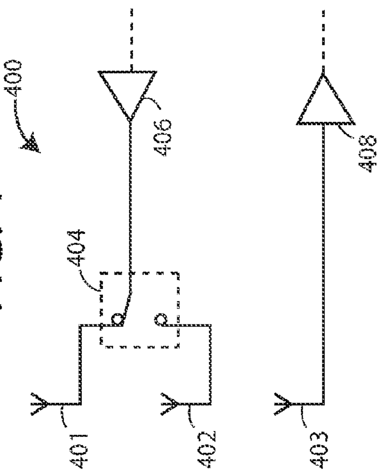

FIG. 4

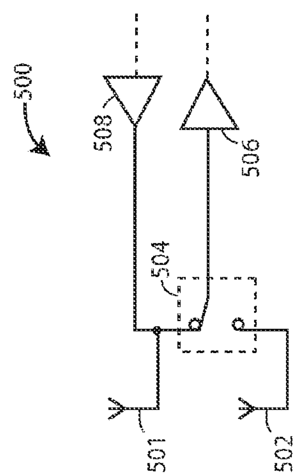

FIG. 5

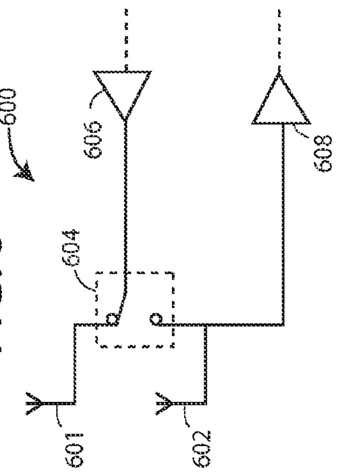

FIG. 6

DIVERSITY TRANSCEIVER FOR A WIRELESS LOCAL AREA NETWORK

RELATED PATENT APPLICATIONS

[0001] This application is a division of U.S. patent application Ser. No. 09/953,461 filed Sep. 14, 2001 and titled DIVERSITY TRANSCEIVER FOR A WIRELESS LOCAL AREA NETWORK, Agent/Attorney Docket No. CISCO-4929, assigned to the assignee of the present invention. U.S. application Ser. No. 09/953,461 is incorporated herein by reference.

[0002] U.S. application Ser. No. 09/953,461 claims priority of U.S. provisional patent applications, Ser. No. 60/277,370 entitled SYSTEM USING SINGLE CHIP WIRELESS LAN MODEM AND SINGLE CHIP RADIO TRANSCEIVER AND APPARATI, METHODS, AND SOFTWARE PRODUCTS USED THEREIN OR THEREWITH, filed Mar. 19, 2001; and also, Ser. No. 60/283,609 entitled WIRELESS COMMUNICATION SYSTEM, filed Apr. 13, 2001. Both are incorporated herein by reference.

BACKGROUND OF THE INVENTION

[0003] 1. Field of the Invention

[0004] The present invention relates to radio transceivers, and more particularly to combinations of receiving antennas and transmitting antennas that reduce signal losses that occur before the first low-noise amplification or after the last power amplification stage.

[0005] 2. Description of Related Art

[0006] Radio transceivers that share one antenna between the receiver and transmitter generally rely on a transmit/receive (T/R) switch to multiplex the antenna. This, of course presupposes half-duplex operation where only the receiver or transmitter is being used at any one time.

[0007] Many radio receiver applications are such that they must reliably receive and demodulate very weak signals. The radio field signal strength can drop so low in some applications that special low-noise amplifier (LNA) modules are integrated with the antenna assembly. A typical such application is the microwave patch antennas used in global positioning system (GPS) navigation receivers. Of course, GPS receivers do not have the complication of an included transmitter or T/R switch. Similarly, losses between the power amplification and the antennas due to diversity and T/R switches limits the available transmitted power and impacts on the transmission reliability.

[0008] Antenna diversity is used in some modern systems to take advantage of the fact that even closely positioned antennas can experience very different induced signal levels. This often requires a "diversity switch" that can be controlled to select one antenna over the other.

[0009] In radio transceiver systems that operate in the 5.0+ GHz spectrum, e.g., radio transceivers that conform to the IEEE 802.11 standard, a typical T/R switch and diversity switch can each insert approximately 1.5 dB of signal loss. At the field strengths that wireless local area networks operate in, their receivers can ill-afford such losses because they come before the earliest point an LNA can be placed. Another approximately 2.0 dB of loss is typically introduced when relatively complex bandpass filters, e.g., bandpass filters with 3 or more poles are added between the antenna diversity switch and T/R switch to eliminate spurious sidebands from the transmitted signal. Such a filter sits in the received signal path too. Altogether, such losses in conventional designs can add up to approximately 5.0 dB for each of the transmitter and receiver to the antenna.

[0010] Local area networks (LAN's) are conventionally interconnected by twisted-wire pairs and shielded cables. A whole class of mobile computing has emerged that depends on various kinds of wireless communication. Amateur radios and cellphones have long been used to connect computer browsers to the Internet, and now wireless devices have been used to build LAN's within a room or building. Better frequency bands and higher allowable power will allow LAN clients to roam around in cities and along highways.

[0011] An industry-standard, the IEEE 802.11 specification, defines the protocol for two types of networks, ad-hoc and client/server networks. An ad-hoc network is a simple network where communications are established between multiple stations in a given coverage area without the use of an access point or server. The standard specifies the etiquette that each station must observe so that they all have fair access to the wireless media. It provides methods for arbitrating requests to use the media to ensure that throughput is maximized for all of the users in the base service set. The client/server network uses an access point that controls the allocation of transmit time for all stations and allows mobile stations to roam from cell to cell. The access point is used to handle traffic from the mobile radio to the wired or wireless backbone of the client/server network. This arrangement allows for point coordination of all of the stations in the basic service area and ensures proper handling of the data traffic. The access point routes data between the stations and other wireless stations or to and from the network server. Typically wireless local area networks (WLAN's) controlled by a central access point will provide better throughput performance.

[0012] The license-free national information structure (U-NII) radio spectrum bands in the United States are assigned to 5.15-5.25, 5.25-5.35, and 5.725-5.825 GHz, and are ideal for wireless ad-hoc LAN communication use. The IEEE-802.11 a protocol prescribes using a training sequence comprising a preamble that enables a receiver to lock on to the carrier and helps get the data demodulation going.

[0013] The IEEE-802.11 a burst transmission begins with a two-part preamble, e.g., a short preamble and a long-preamble. The exact boundary point between the short and long preambles is important to the receiver's subsequent demodulation process, and must be found quickly in an environment where the carrier frequency and code phase are uncertain. Signal fading, multipath interference, and channel distortion can make signal acquisition less certain in a typical receiver.

SUMMARY OF THE INVENTION

[0014] An object of the present invention is to provide a wireless local area network.

[0015] Another object of the present invention is to improve radio reception in a wireless local area network.

[0016] A further object of the present invention is to provide a more reliable radio transceiver.

[0017] Briefly, a transceiver embodiment of the present invention for operating in a wireless local area network comprises a 5.0+ GHz radio transceiver with reduced losses comprised of two receiving antennas and one transmitting antenna or one receiving antenna and two transmit antennas. A transmitter power amplifier output is connected to the transmitting antenna through a bandpass filter to control spurious signal output. Each receiving antenna is fitted with its own low-noise amplifier followed by a simple bandpass filter. Each bandpass filter feeds a diversity switch with a single output to a single receiver. The radio transceiver constitutes a physical-layer (PHY) part of a wireless local-area network.

[0018] The above and still further objects, features, and advantages of the present invention will become apparent upon consideration of the following detailed description of specific embodiments thereof, especially when taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] FIG. **1** is a functional block diagram of a first wireless local area network system embodiment of the present invention in which there are two receiving antennas connected to a diversity switch;

[0020] FIG. **2** is a functional block diagram of a second wireless local area network system embodiment of the present invention in which the transmitter is connected to two antennas through a diversity switch;

[0021] FIG. **3** is a schematic diagram of a receiver antenna diversity arrangement that requires no T/R switch in an alternative embodiment of the present invention;

[0022] FIG. **4** is a schematic diagram of a transmitter antenna diversity arrangement that requires no T/R switch in another alternative embodiment of the present invention;

[0023] FIG. **5** is a schematic diagram of a receive-antenna diversity arrangement that requires no T/R switch and uses only two antennas in an alternative embodiment of the present invention; and

[0024] FIG. **6** is a schematic diagram of a transmit-antenna diversity arrangement that requires no T/R switch and uses only two antennas in another alternative embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0025] FIG. **1** illustrates a wireless local area network (LAN) system embodiment of the present invention, and referred to herein by the general reference numeral **100**. Such is preferably based on orthogonal frequency division multiplexing (OFDM), and quadrature phase shift keying (QPSK) and quadrature amplitude modulation (QAM) of signals transmitted in the 5 GHz frequency spectrum. The wireless LAN system **100** includes a wireless network **101** that may be connected to the Internet, a PHY-transmitter **102**, and a PHY-receiver **103**. Such all preferably conform to the IEEE-802.11*a* Specification for a physical layer (PHY) interface in a wireless local area network which allows mobile clients on an ad-hoc basis.

[0026] In a typical embodiment, the transmitter **102** comprises a one or more digital signal processing elements (DSP) **104** which implement a forward error correction (FEC) coder **106**, an interleaving and mapping process **108**, an inverse fast Fourier transform processor **110**, and a symbol wave shaper **112**. The DSP **104** outputs in-phase (I) and quadrature-phase (Q) signals that are input to an IQ modulator **114** driven by a local oscillator **116**. The modulated output is sent to a mixer **118** for up-conversion to the 5 GHz band. A second local oscillator **120** provides the necessary carrier frequency. A high power amplifier (HPA) **122** has any spurious sidebands removed by a bandpass filter **124** before being output to a transmitter antenna **126**. Such filter **124** is necessarily a complex type, e.g., a multi-pole filter that in one embodiment has as few as 2-3 poles, and in another has 6-8 poles. A radio up-link **127** is received by the wireless network **101**, and communicates Internet traffic, for example. In general, the transmitter **102** can be implemented with conventional methods and components. One embodiment is a transmitter part of a transceiver integrated circuit implemented in CMOS, with one or more external components, e.g., the complex bandpass filter.

[0027] Conventional practice puts diversity and transmit switching before a single LNA. By ensuring that the transmit antenna to receive antenna isolation is better than, for example, 30 dB and that the LNA power handling limit is better than about −10 dBm, then transmit power levels of about 10 dBm can be handled with the present invention. The advantage is the elimination of these switching losses.

[0028] In alternative transmitter embodiments of the present invention, two power amplifiers are used with a single diversity switch in front of the amplifiers. Thus the diversity switch losses do not detract from the achievable power output. Only one such power amplifier has its power switched on before transmission, to save overall power consumption. This is best done using a gradual, i.e., modulated switch-on, e.g., using a ramp function as described in co-pending U.S. patent application Ser. No. 09/877,398 to Adams, et al., filed Jun. 8, 2001, and assigned to the assignee of the present invention.

[0029] The receiver **103** receives a radio down-link **128** that is typically transmitted in bursts. Each burst is begun with a training sequence, e.g., a short and long preamble. In one embodiment, the receiver **103** includes at least two receiver antennas **130** and **131** each followed by a low-noise amplifier (LNA) **132** and **133**. The antennas are preferably separated by at least one-half wavelength.

[0030] A pair of bandpass filters **134** and **135** precede a diversity switch **136**. These are typically not the more complex 6-8 pole types needed by the transmitter. Insertion losses in filters **134** and **135** range 0.5-0.6 dB, and insertion loss through the diversity switch **136** is about 1.5 dB. Critically, both these losses occur after LNA **132** and **133**.

[0031] In latter stages of the receiver **103**, measurements are made on the received signals to decide whether diversity switch **136** should select signals from antenna **130** or antenna **131**. The physical diversity of the two antennas will often cause one to have a better quality view of radio down-link **128**.

[0032] In situations with significant multipath in the transmission path from transmitter to receiver, two antennas separated by as little as one half wavelength at one end or the other will suffer different amounts of signal fading. For

Rayleigh faded signals corresponding to a large number of multiple paths, this means that 3 dB or more average improvement may typically be achieved by selecting the best antenna on transmit or, in the case of receive diversity, best antenna on receive, or, in the case of transmit and receive diversity, the best antenna on both.

[**0033**] A local oscillator **138** and a first mixer **140** produce an intermediate frequency (IF). An automatic gain control (AGC) amplifier **142** smoothes out signal-strength variations and drives an IQ-detector **144**. A second local oscillator **146** provides the carrier necessary to derive the I and Q samples. Automatic frequency control (AFC) clock recovery can be skipped if frequency offset errors are corrected in later digital processing. One or more receiver signal processing elements (receiver-DSP **148**) implement a fast Fourier transform process **150**, a demapping and deinterleaving process **152**, and an FEC decoder **154**. The receiver-DSP **148** further includes the necessary digital logic needed for carrier frequency offset determination and correction. The higher levels of a mobile, computer-network client are represented by a media access controller (MAC) **156** and a client agent software **158**.

[**0034**] FIG. **2** illustrates another wireless local area network (LAN) system embodiment of the present invention, and is referred to herein by the general reference numeral **200**. Such is also based on orthogonal frequency division multiplexing (OFDM), and modulation of signals, e.g., quadrature phase shift keying (QPSK) of signals transmitted in the 5 GHz frequency spectrum. As in system **100**, the wireless LAN system **200** includes a wireless computer-data network **201** that may be connected to the Internet, a PHY-transmitter **202** with antenna diversity, and a PHY-receiver **203**.

[**0035**] In a typical embodiment, the transmitter **202** comprises a digital signal processor (DSP) **204** which implements a forward error correction (FEC) coder **206**, an interleaving and mapping process **208**, an inverse fast Fourier transform processor **210**, and a symbol wave shaper **212**. The DSP **204** outputs in-phase (I) and quadrature-phase (Q) signals that are input to an IQ modulator **214** driven by a local oscillator **216**. The modulated output is sent to a mixer **218** for up-conversion to the 5 GHz band. A second local oscillator **220** provides the necessary carrier frequency.

[**0036**] A high power amplifier (HPA) **222** is connected through an antenna-diversity switch **223**. Such allows a test transmission to be made using one transmitter antenna, and if no remote response is elicited from the transmission, then a switch is made to transmit from another antenna. The assumption is that the slight difference in diversity may be enough to get the transmitted signal to the intended receivers.

[**0037**] The two outputs of the diversity switch **223** have any spurious sidebands removed by a filter **224** or **225** before being output to a corresponding transmitter antenna **226** or **227**. Such filter **224** is necessarily a relatively complex type, e.g., a multi-pole one with as few as 2-3 and as many as 6-8, or even more poles. A radio up-link **228** is received by the wireless network **201**, and communicates Internet traffic, for example.

[**0038**] The receiver **203** receives a radio down-link **229** that is typically transmitted in bursts. The receiver **203** includes at least two receiver antennas **230** and **231** each followed by a low-noise amplifier (LNA) **232** and **233**. A pair of bandpass filters **234** and **235** precede a diversity switch **236**. These are typically not the relatively complex multi-pole types needed by the transmitter. Insertion losses in filters **234** and **235** range 0.5-0.6 dB, and insertion loss through the diversity switch **236** is about 1.5 dB. Critically, both these losses occur after LNA **232** or **233**.

[**0039**] Alternatively, receiver **203** uses only a single antenna **230**, a single LNA **232**, a single bandpass filter **234**, and no diversity switch. The transmitter antenna diversity is relied on more heavily in such situation.

[**0040**] In latter stages of the receiver **203**, measurements are made on the received signals to decide whether diversity switch **236** should select signals from antenna **230** or antenna **231**. The physical diversity of the two antennas will often cause one to have a better quality view of radio down-link **229**.

[**0041**] A local oscillator **238** and a first mixer **240** produce an intermediate frequency (IF). An automatic gain control (AGC) amplifier **242** smoothes out signal-strength variations and drives an IQ-detector **244**. A second local oscillator **246** provides the carrier necessary to derive the I and Q samples. Automatic frequency control (AFC) clock recovery can be skipped if frequency offset errors are corrected in later digital processing. A receiver-DSP **248** comprises a fast Fourier transform process **250**, a demapping and deinterleaving process **252**, and an FEC decoder **254**. The receiver-DSP **248** further includes the necessary digital logic needed for carrier frequency offset determination and correction.

[**0042**] The higher levels of a mobile, computer-network client are represented by a media access controller (MAC) **256** and a client agent software **258**.

[**0043**] FIG. **3** represents a receiver antenna diversity arrangement **300** that requires no T/R switch in an alternative embodiment of the present invention. A set of three antennas **301**-**303** are physically diversified. Antenna **301** is a transmit antenna driven by a power amplifier **304**. Antennas **302** and **303** are receive antennas that are multiplexed through by a receive-diversity switch **306** to a low-noise amplifier (LNA) **308**.

[**0044**] FIG. **4** represents a transmitter antenna diversity arrangement **400** that requires no T/R switch in another alternative embodiment of the present invention. A set of three antennas **401**-**403** include two receive antennas **401** and **402** connected to a transmit-diversity switch **404**. A power amplifier **406** is selectively connected to antennas **401** and **402**. A low-noise amplifier (LNA) **408** receives its signals from antenna **403**.

[**0045**] FIG. **5** represents a receive-antenna diversity arrangement **500** that requires no T/R switch and uses only two antennas **501** and **502** in an alternative embodiment of the present invention. A receive-diversity switch **504** multiplexes the two antennas to a low-noise amplifier (LNA) **506**. A power amplifier **508** drives only antenna **501**.

[**0046**] FIG. **6** represents a transmit-antenna diversity arrangement **600** that also requires no T/R switch. It uses only two antennas **601** and **602** in another alternative embodiment of the present invention. A transmit-diversity switch **604** multiplexes the two antennas to a power amplifier **606**. The antenna **602** alone is connected to a low-noise amplifier (LNA) **608**.

[**0047**] The antenna diversity described herein maybe applied in a transceiver at the receiver, at the transmitter, or both.

[**0048**] Although particular embodiments of the present invention have been described and illustrated, such is not intended to limit the invention. Modifications and changes will no doubt become apparent to those skilled in the art, and it is intended that the invention only be limited by the scope of the appended claims.

1. A method of increasing the available radio signal in a wireless local area network, the method comprising the steps of:

separating radio transmission and reception signals into corresponding transmitter and receiving antennas;

providing at least two transmitter antennas or at least two receiver antennas for diversity; and

multiplexing between multiple said antennas with at least one of a receiver diversity switch and a transmitter diversity switch;

wherein a transmit/receive switch and its concomitant signal insertion loss is eliminated from a path between an antenna receiving wireless local area network transmission signals an a first stage of radio-frequency amplification.

2. A method of increasing the available radio signal in a wireless local area network, the method comprising the steps of:

separating radio transmission and reception signals into corresponding transmitter and receiving antennas;

providing at least two transmitter antennas or at least two receiver antennas for diversity; and

multiplexing between multiple said antennas with at least one of a receiver diversity switch and a transmitter diversity switch;

wherein, a multi-pole bandpass filter for said radio transmission signals and its concomitant signal insertion loss is eliminated from a path between an antenna receiving wireless local area network transmission signals an a first stage of radio-frequency amplification.

3. A method of increasing the available radio signal in a wireless local area network, the method comprising the steps of:

separating radio transmission and reception signals into corresponding transmitter and receiving antennas;

providing at least two transmitter antennas or at least two receiver antennas for diversity; and

multiplexing between multiple said antennas with at least one of a receiver diversity switch and a transmitter diversity switch;

wherein, a first stage of radio-frequency amplification is placed in a path after an antenna receiving wireless local area network transmission signals and before a simple bandpass filter for said radio reception signals and its concomitant signal insertion loss.

4. A method of increasing the available radio signal in a wireless local area network, the method comprising the steps of:

separating radio transmission and reception signals into corresponding transmitter and receiving antennas;

providing at least two transmitter antennas or at least two receiver antennas for diversity; and

multiplexing between multiple said antennas with at least one of a receiver diversity switch and a transmitter diversity switch;

wherein, a transmit/receive switch and its concomitant signal insertion loss is eliminated from a path between an antenna receiving wireless local area network transmission signals an a first stage of radio-frequency amplification;

wherein, a multi-pole bandpass filter for said radio transmission signals and its concomitant signal insertion loss is eliminated from a path between an antenna receiving wireless local area network transmission signals an a first stage of radio-frequency amplification; and

wherein, a first stage of radio-frequency amplification is placed in a path after an antenna receiving wireless local area network transmission signals and before a simple bandpass filter for said radio reception signals and its concomitant signal insertion loss.

5. A means for increasing the available radio signal in a wireless local area network, comprising:

means for separating radio transmission and reception signals into corresponding transmitter and receiving antennas;

means for providing at least two transmitter antennas or at least two receiver antennas for diversity; and

means for multiplexing between multiple said antennas with at least one of a receiver diversity switch and a transmitter diversity switch;

wherein a transmit/receive switch and its concomitant signal insertion loss is eliminated from a path between an antenna receiving wireless local area network transmission signals an a first stage of radio-frequency amplification.

6. A means for increasing the available radio signal in a wireless local area network, comprising:

means for separating radio transmission and reception signals into corresponding transmitter and receiving antennas;

means for providing at least two transmitter antennas or at least two receiver antennas for diversity; and

means for multiplexing between multiple said antennas with at least one of a receiver diversity switch and a transmitter diversity switch;

wherein, a multi-pole bandpass filter for said radio transmission signals and its concomitant signal insertion loss is eliminated from a path between an antenna receiving wireless local area network transmission signals an a first stage of radio-frequency amplification.

7. A means for increasing the available radio signal in a wireless local area network, comprising:

means for separating radio transmission and reception signals into corresponding transmitter and receiving antennas;

means for providing at least two transmitter antennas or at least two receiver antennas for diversity; and

means for multiplexing between multiple said antennas with at least one of a receiver diversity switch and a transmitter diversity switch;

wherein, a first stage of radio-frequency amplification is placed in a path after an antenna receiving wireless local area network transmission signals and before a simple bandpass filter for said radio reception signals and its concomitant signal insertion loss.

8. A means for increasing the available radio signal in a wireless local area network, the means comprising the steps of:

means for separating radio transmission and reception signals into corresponding transmitter and receiving antennas;

means for providing at least two transmitter antennas or at least two receiver antennas for diversity; and

means for multiplexing between multiple said antennas with at least one of a receiver diversity switch and a transmitter diversity switch;

wherein, a transmit/receive switch and its concomitant signal insertion loss is eliminated from a path between an antenna receiving wireless local area network transmission signals an a first stage of radio-frequency amplification;

wherein, a multi-pole bandpass filter for said radio transmission signals and its concomitant signal insertion loss is eliminated from a path between an antenna receiving wireless local area network transmission signals an a first stage of radio-frequency amplification; and

wherein, a first stage of radio-frequency amplification is placed in a path after an antenna receiving wireless local area network transmission signals and before a simple bandpass filter for said radio reception signals and its concomitant signal insertion loss.

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